Understanding the Fundamentals of Twin Screw Compounding

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Agenda

Fundamentals of Twin Screw Compounding

- Feeding – Refilling optimization
- Screw elements for different tasks

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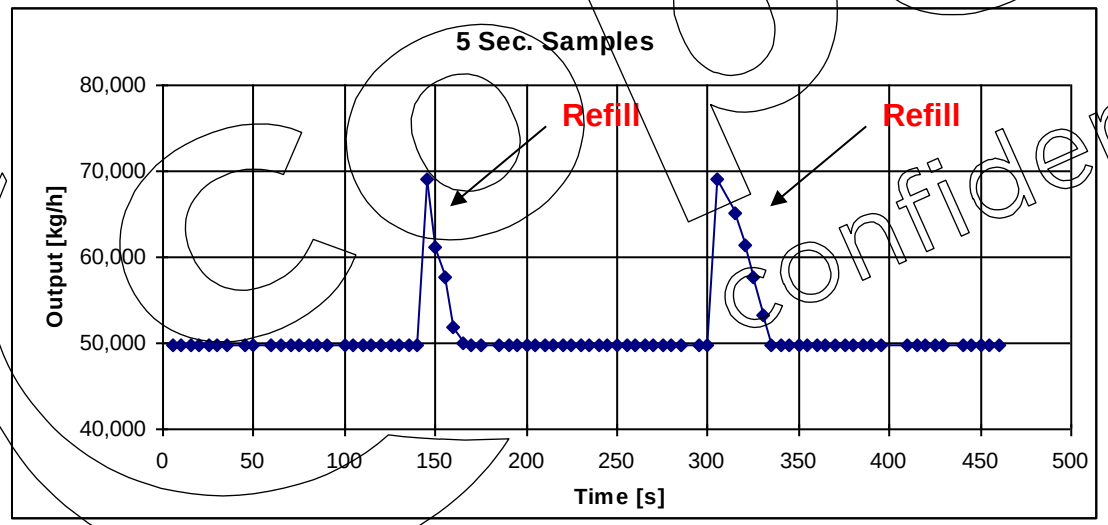
Optional Chapter Navigation

Unit Operations: Upstream feeding - refilling

A correct feeder performance is important to ensure a stable compounding process. When refilling of the feeding system is wrong, refill limits may create a short overflow of the material which can even stop the process

Example: Material buffer in the hopper is too low; when the feeders starts to refill, material with a low bulk density starts to fluidize. The feeder control system will not show the overflow because during refilling the feeder is in the volumetric mode !!



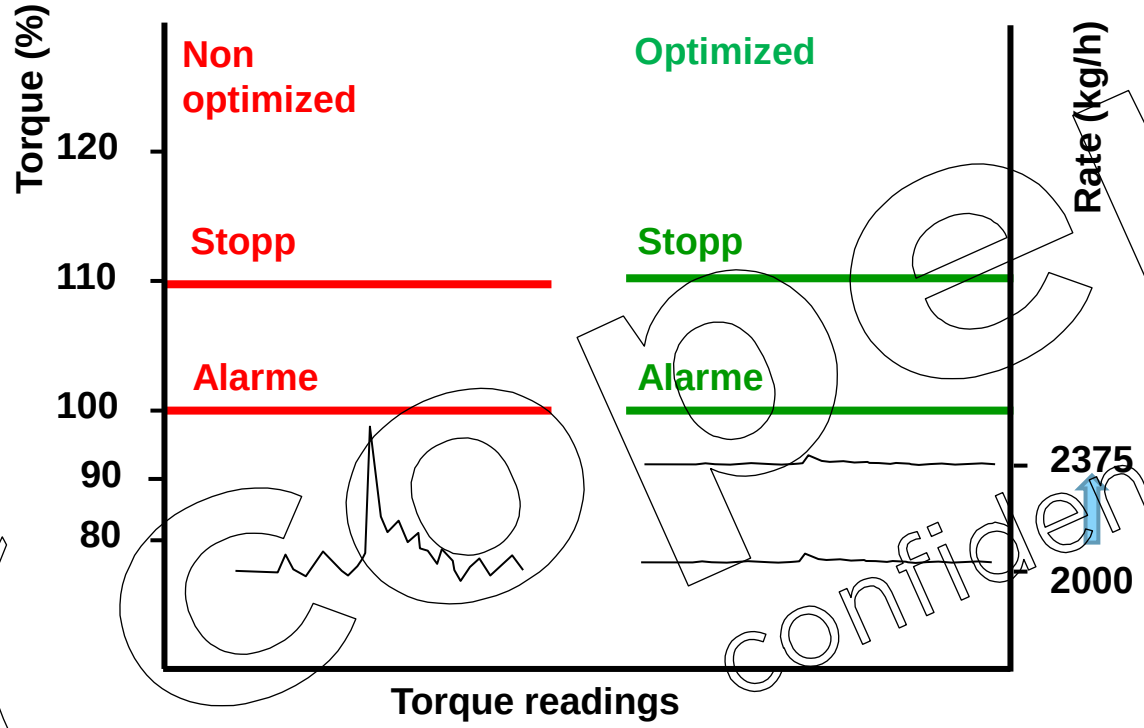


- Torque fluctuations
- Unstable process
- Decreased Output:
  80% Md instead of 95 % Md

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Unit Operations: Upstream feeding – refilling

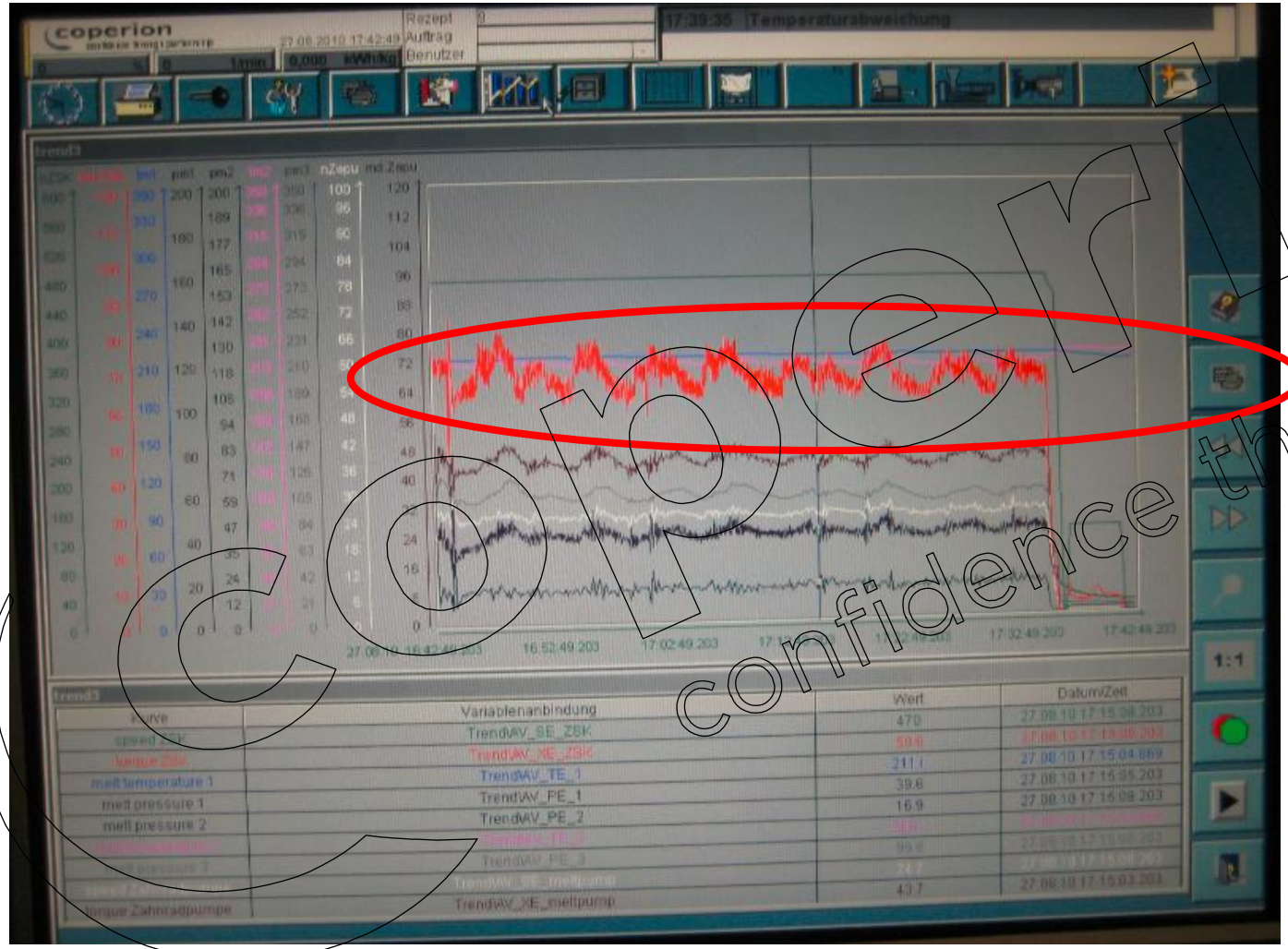
Torque peaks at extruder



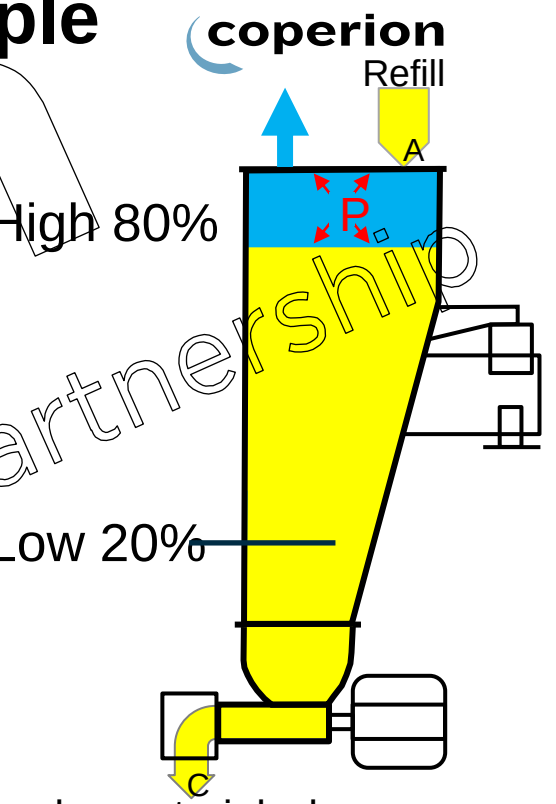
- Not optimized system: regular peaks that can lead to an Alarm or stop due to overtorque.
- Optimized system: smooth and flat torque graph. It allows to increase throughput.

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Unit Operations: Upstream feeding – refilling example



Actual level of refill: 20-80% of the hopper volume

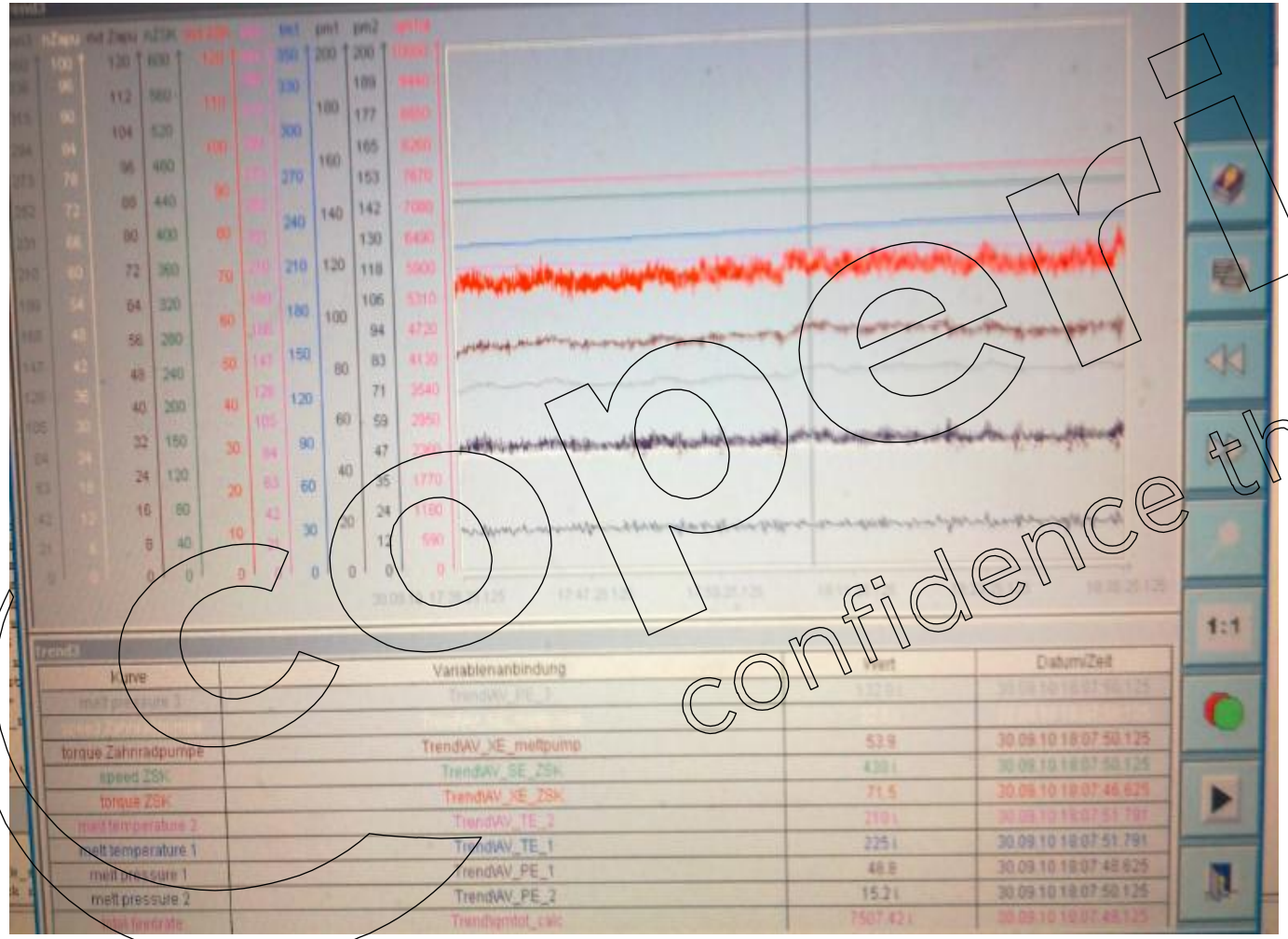


Consequences:

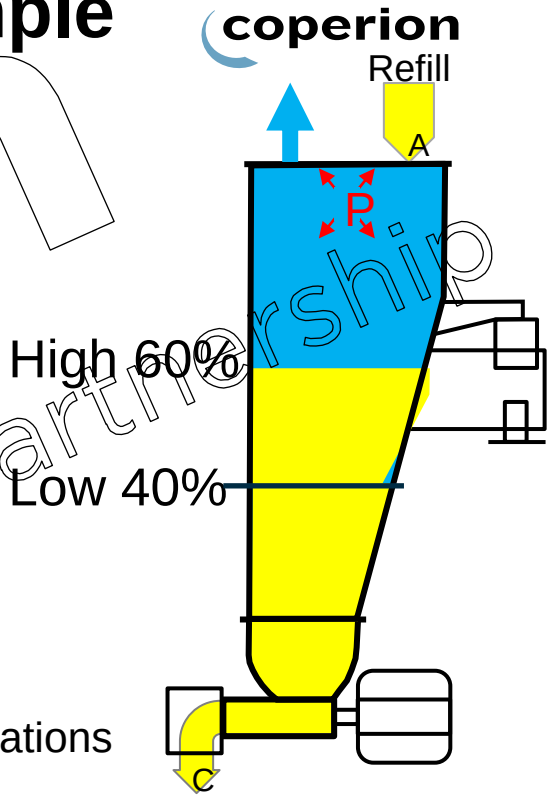
- Fluidization of powder material when refilling starts at 20 %
- Buffer of 20% not stable when fresh material enters the feeder =>shooting
- Torque peaks at extruder visible
- Broken screw tips when too much filler was fed

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Unit Operations: Upstream feeding – refilling example



Better Refill level:
40-60%



Benefits:

- Reduced fluctuations
- Full utilization of torque
- Homogeneous dispersion quality
- Risk of shut-downs minimized
- Superior control technology during Refill allows better utilization of machines

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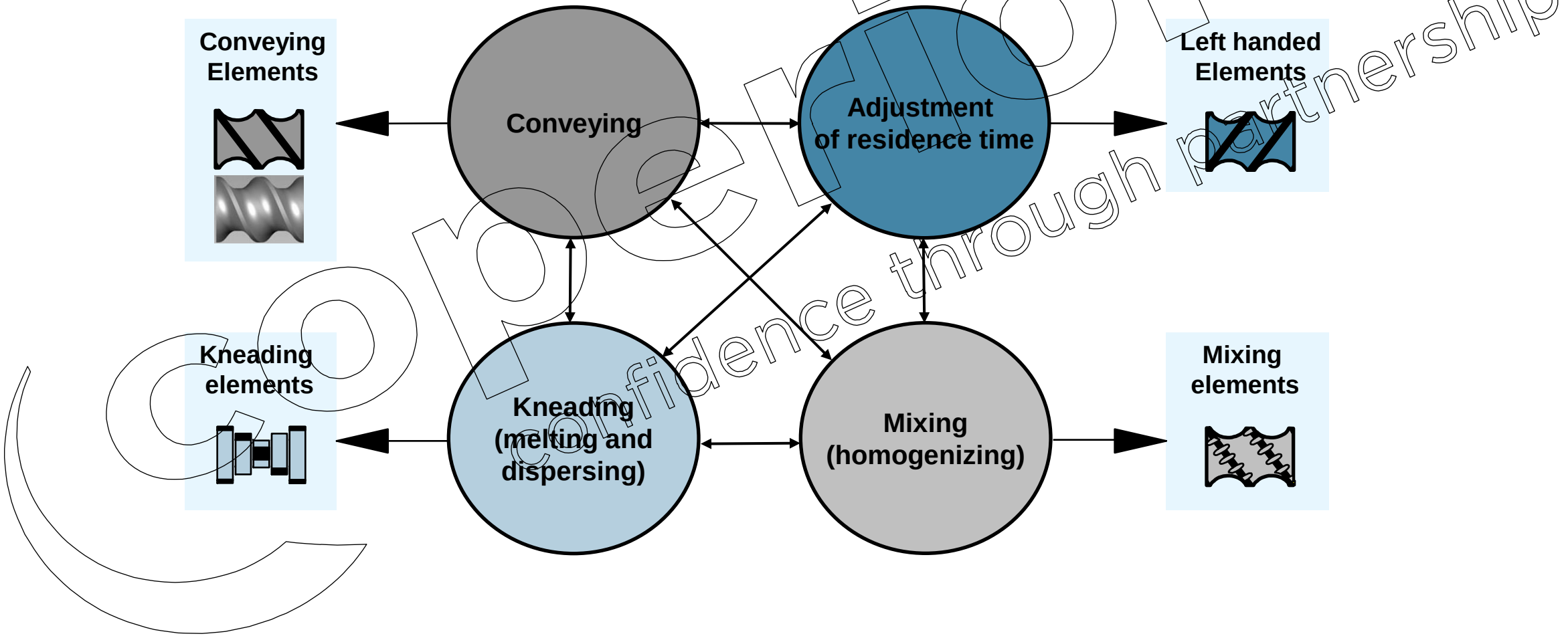
Screw elements in focus

Sample images



Characteristics

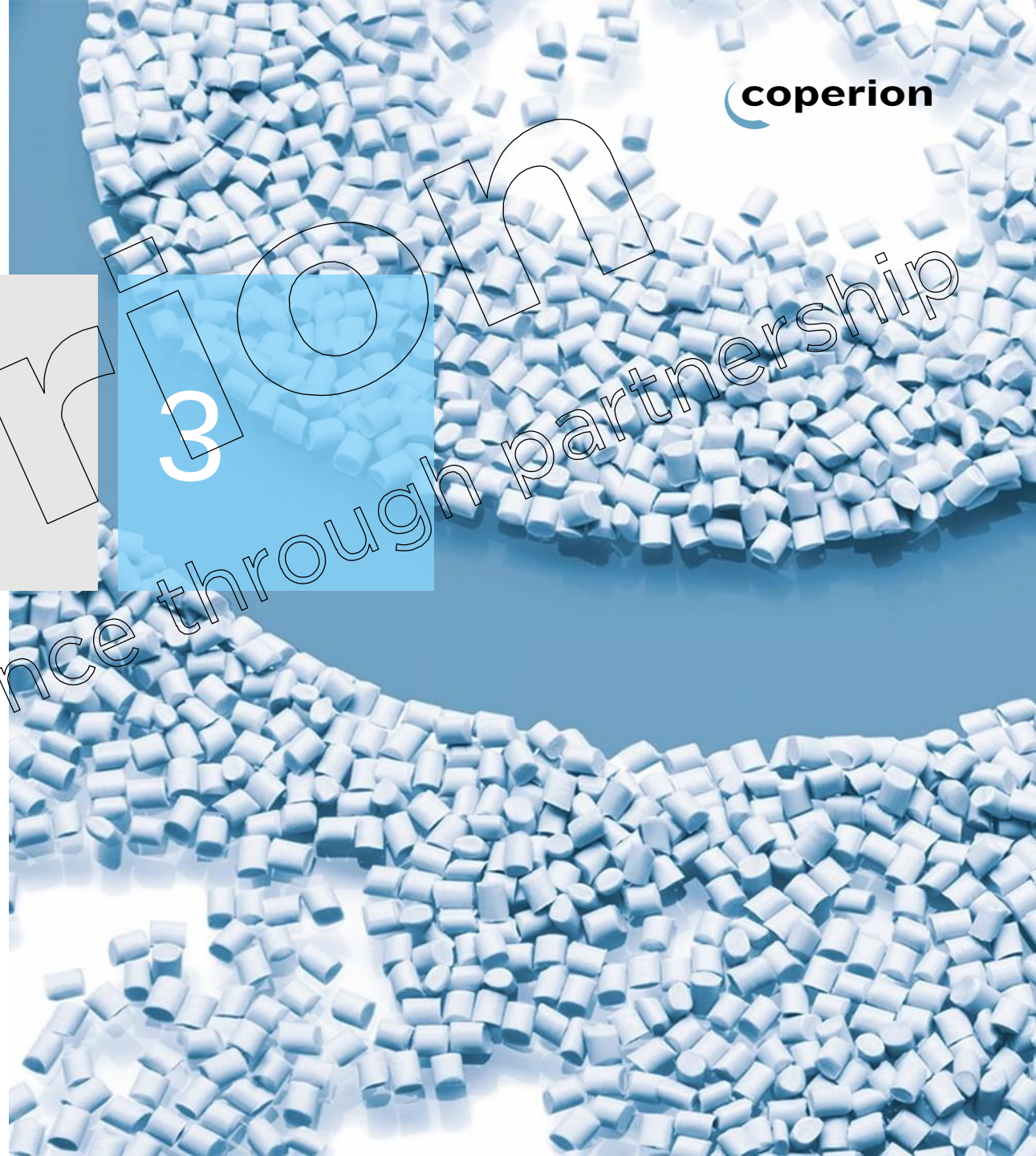
Element types and principle effects



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Conveying elements

3



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Conveying elements

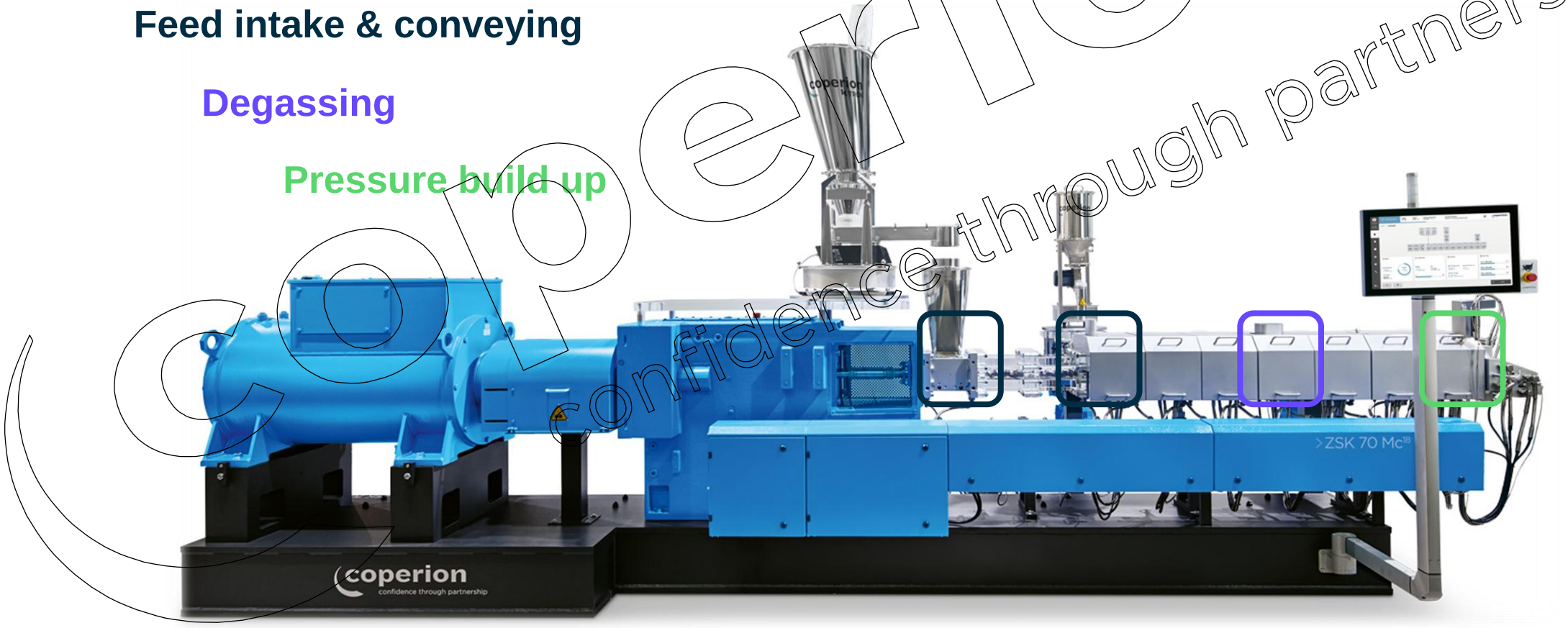
Extruder layout

In which areas are conveying elements essential?

Feed intake & conveying

Degassing

Pressure build up



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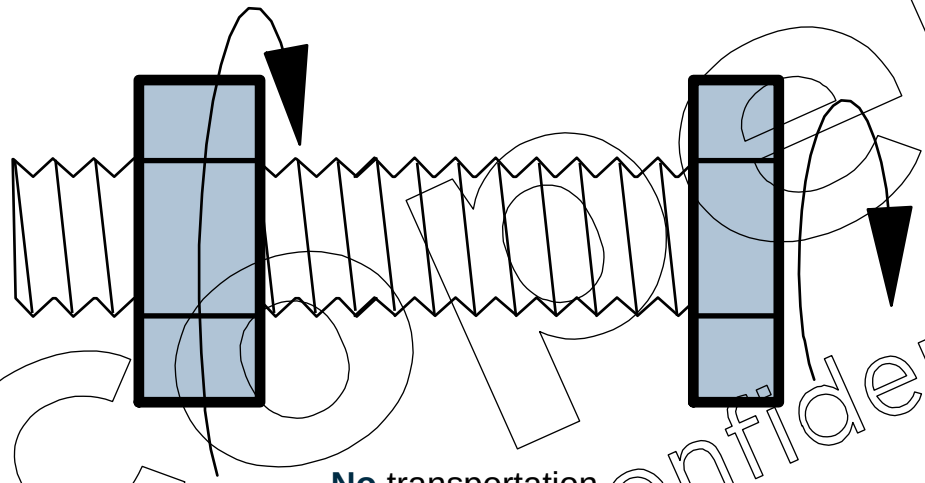
Characteristics

Conveying mechanism

The conveying mechanism of an extruder is determined by the ratio of the friction between product to the barrel wall and product to the screw element.

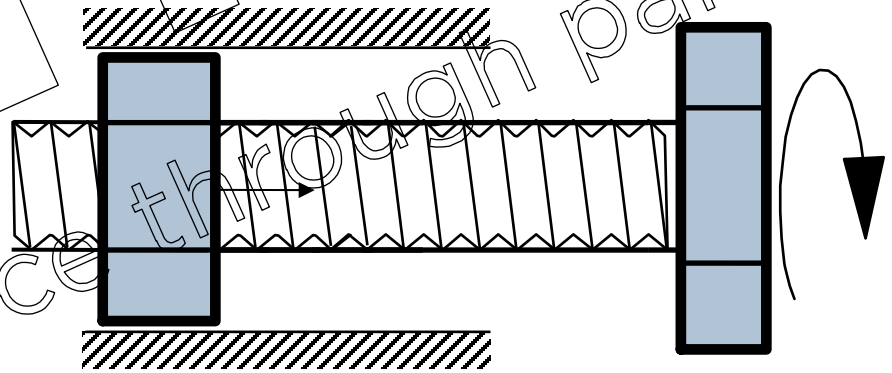
Material friction:

screw >> barrel



No transportation
Material sticking to the screw

screw << barrel



Good transportation

Polymer transport requirements

- Low friction at screw
- High friction at barrel wall (bolt / nut effect) improves the product conveying

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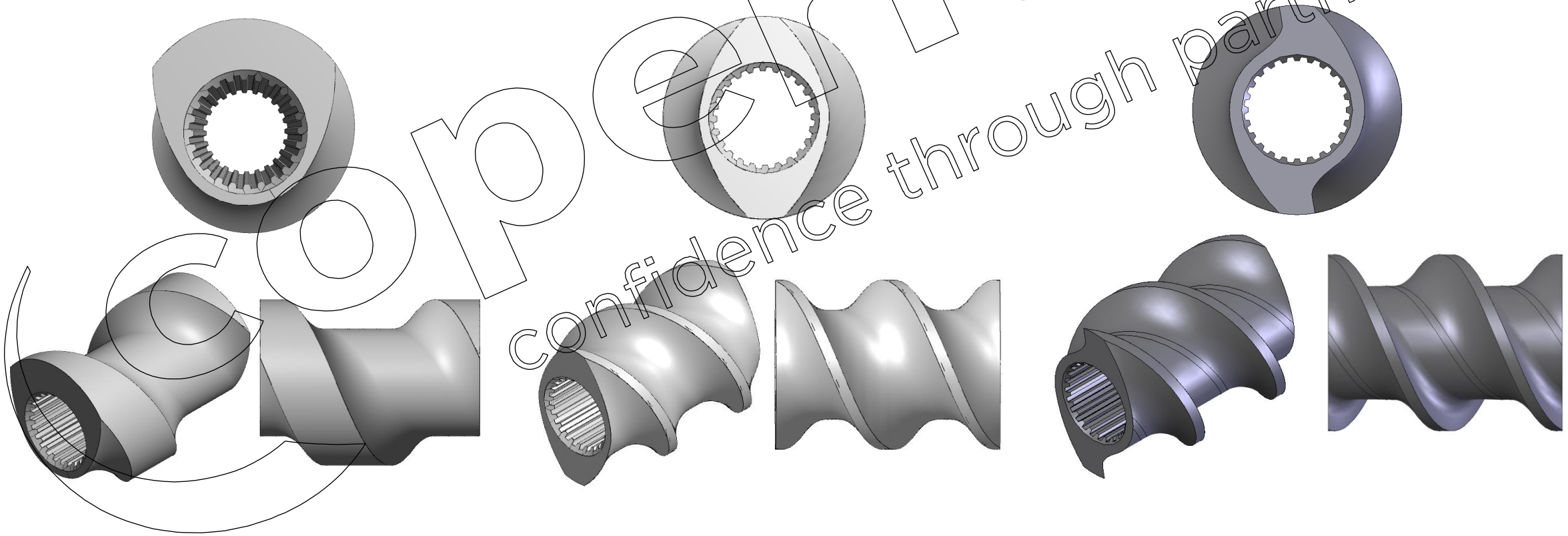
Conveying elements

Major types

Single - flighted

Two - flighted

Undercut

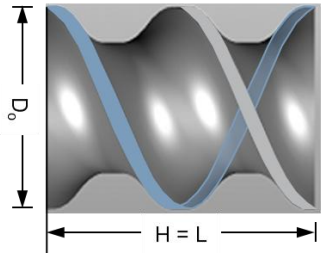


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Conveying elements

Fill factor – Pitch H

Definition Pitch H:
Axial length L [mm] required to complete one helix of the screw



60/60

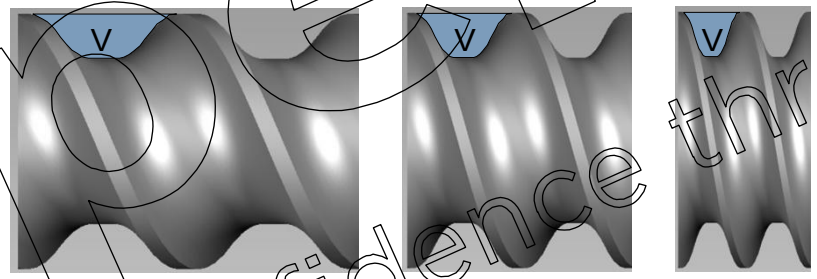
Half element

60/30

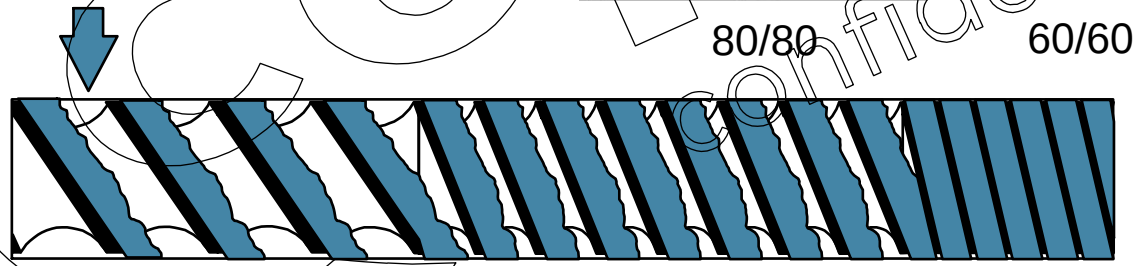
The **pitch H** of a conveying element **determins** the **free volume V** of the screw channel.

The **pitch H** also influences the conveying efficiency of the element

H1 > H2 > H3



80/80 60/60 40/40



With reduced pitch, the volume in the screw channels is reduced.
As a consequence the fill factor will be increased.

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Conveying elements

Optimal screw pitch & conveying efficiency η

$$Q = F \cdot H \cdot n \cdot \varepsilon \cdot \eta \cdot \gamma$$

Rate Kg/h

Free cross section cm²

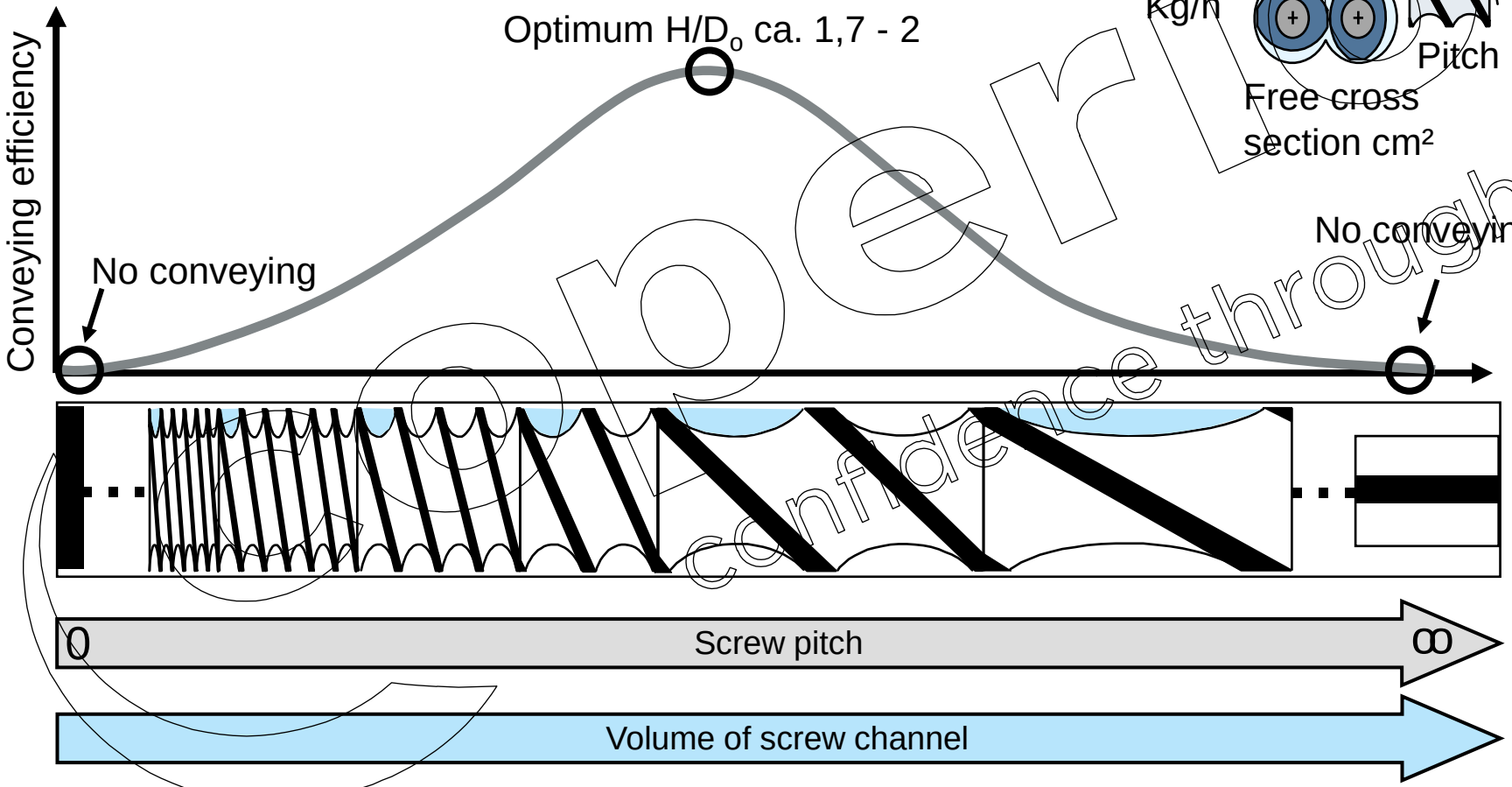
Pitch

rpm

Filling degree %

Conveying efficiency %

Bulk density kg/L



Conveying efficiency depends on pitch, type of element (1 F, 2 F, 3 F, conveying, kneading element), wall adhesion (friction between product and barrel wall)

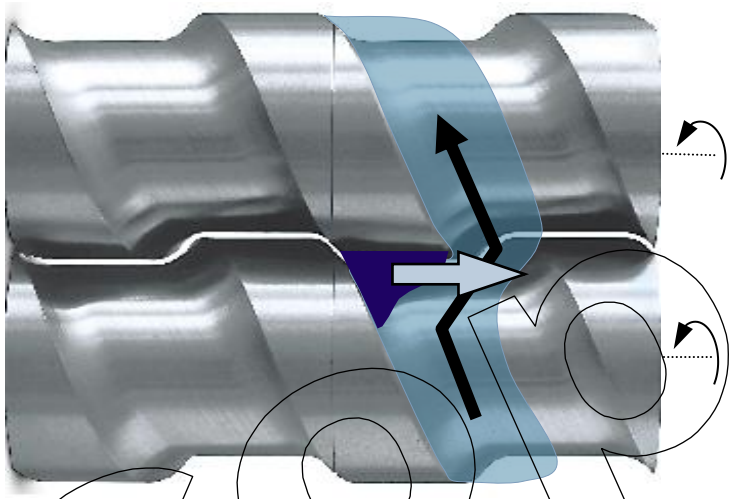
$$\eta = 0{,}5$$

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Conveying elements

Conveying mechanism

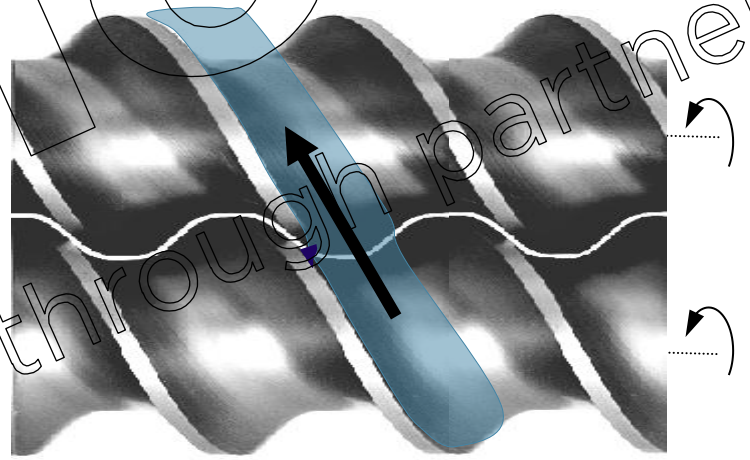
Single-flighted elements



Product movement

Reduced movement of the product from one screw to the other due to big crest and large wedge restraint
➔ **Improved axial transportation (conveying efficiency)**

Two-flighted elements



Product movement

Product mainly moves from one screw to the other screw
➔ **Reduced axial transportation (conveying efficiency)**

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Conveying elements

Undercut (SK) elements

Self cleaning profile

vs

Undercut profile (SK)



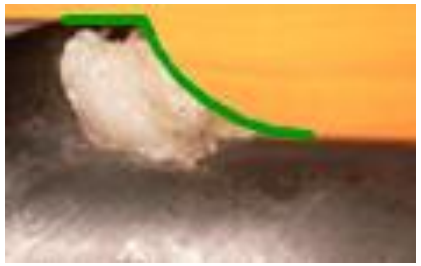
Free cross section: **100%**

Free cross section: approx. **115%**

Pros and cons´

- Higher free volume at the same pitch
- Sticky products can rebuild the self-cleaning profile
- In the intermeshing area of the screws there is an open gap which reduces the conveying efficiency

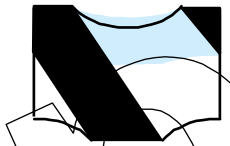
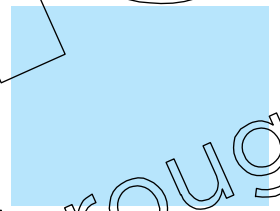
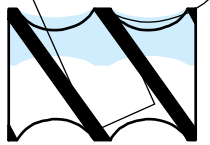
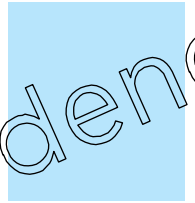
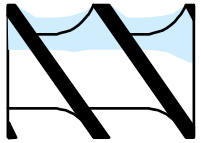
➔ Area of operation: Main feed



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Conveying elements

Free volume and conveying efficiency - Overview

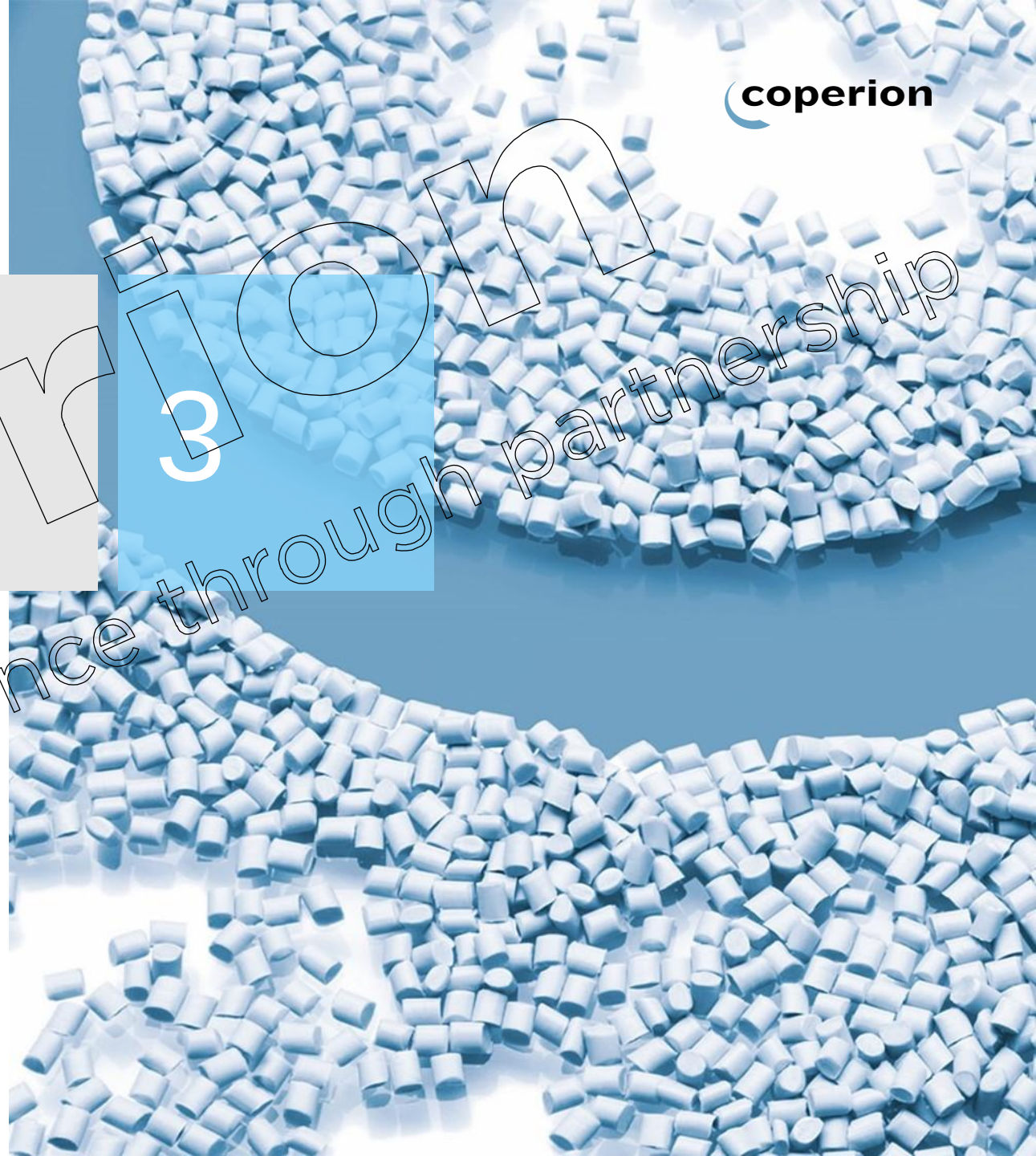
Type of element	Free volume	Conveying efficiency
1-flighted element 		
Standard element 		
Undercut element 		

 Bigger solids

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Adjustment of residence time

3

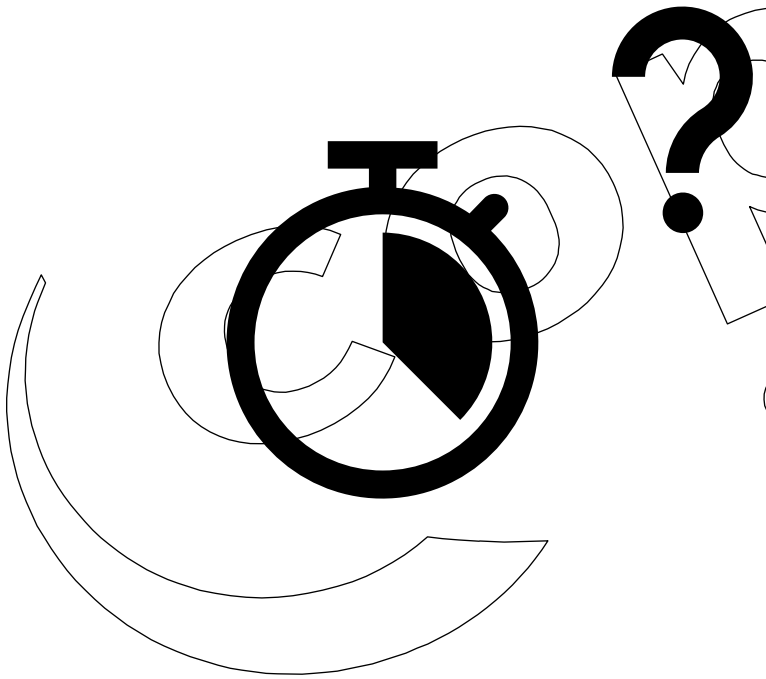


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Adjustment of residence time

Extruder layout

What factors are influenced by residence time?







Adjustment of residence time

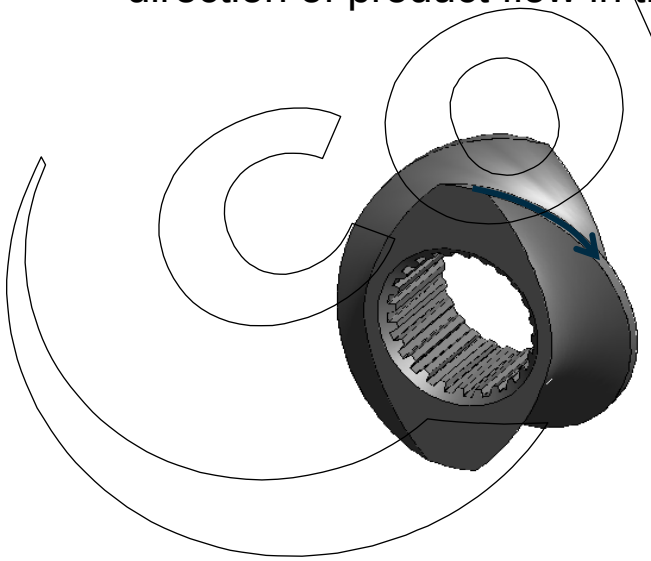
Right and left handed elements

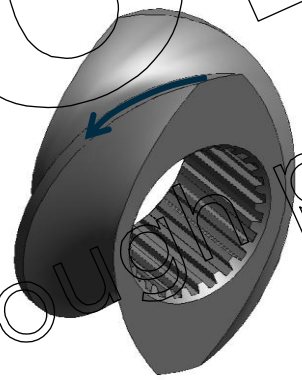
Right handed elements

Conveying direction of the element

same as

direction of product flow in the extruder





Left handed elements

Conveying direction of the element

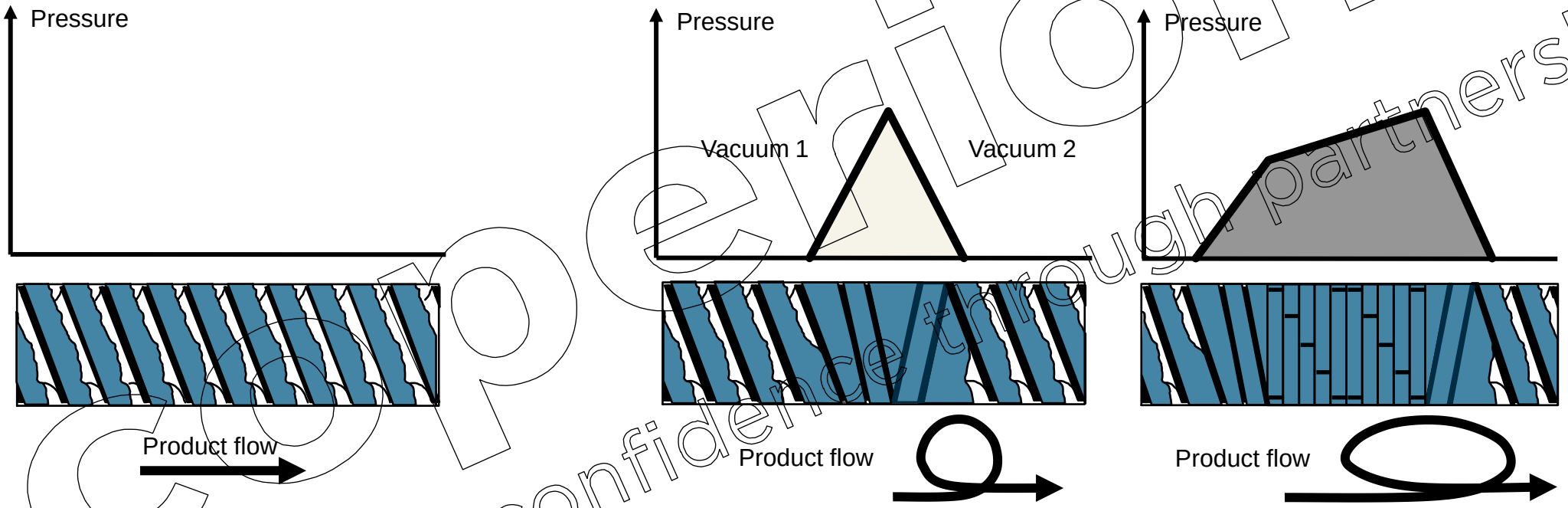
contrary to

the direction of product flow in the extruder

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Adjustment of residence time

Influence of screw set-up on pressure



Right handed elements

Elements are partly filled with polymer
→ This section is pressureless

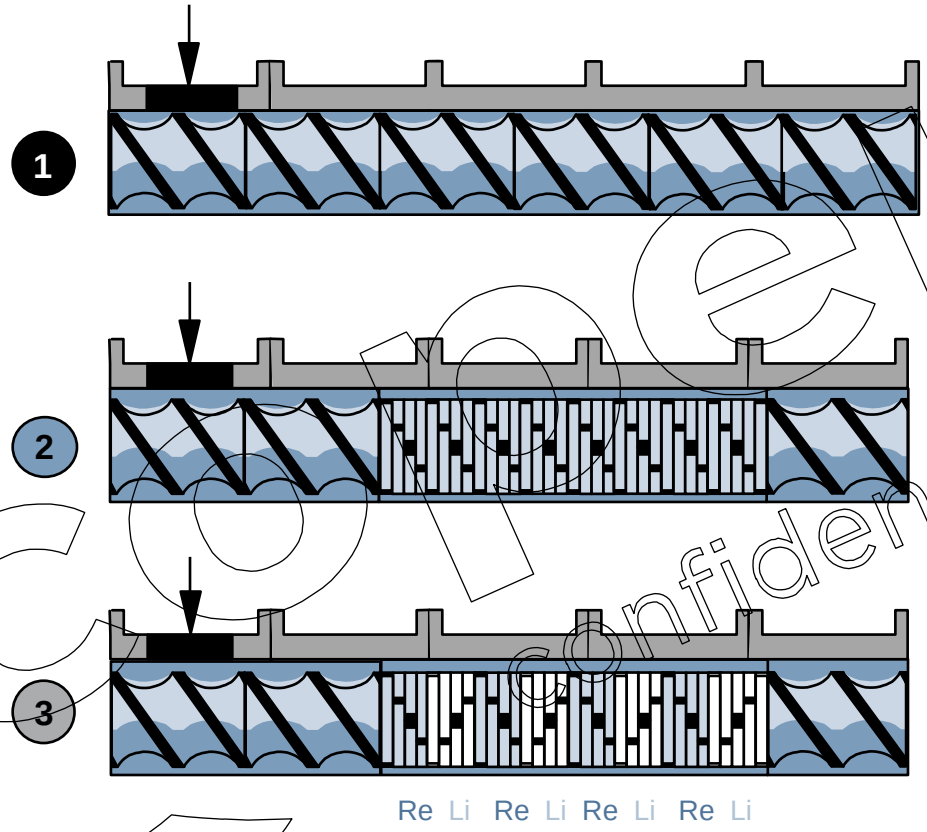
Left handed elements

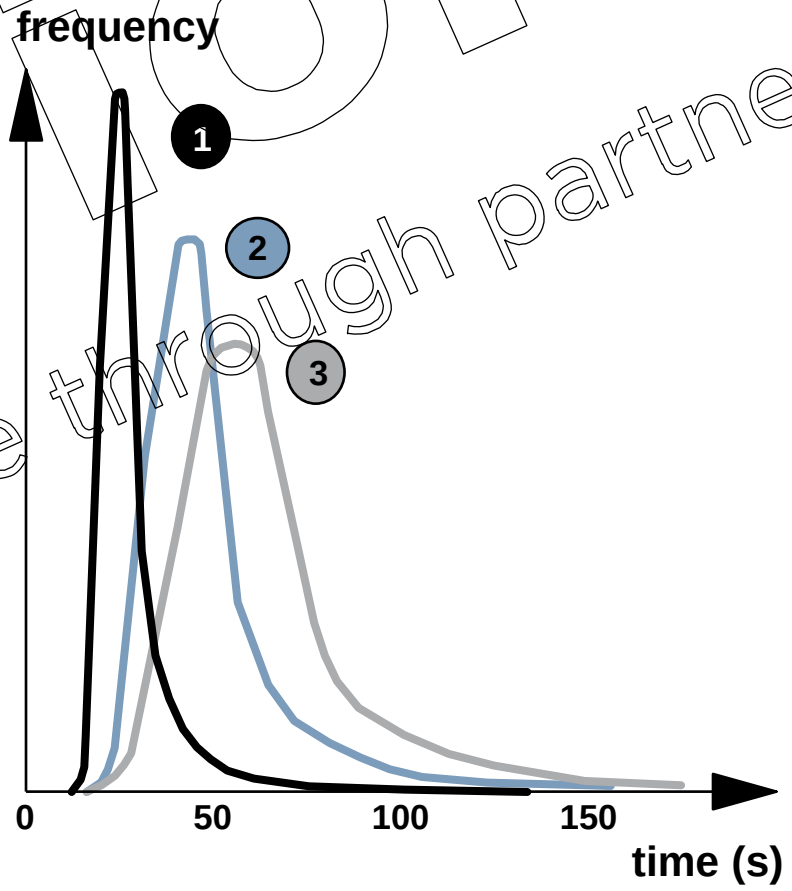
Elements restrict the polymer flow
→ The upstream located section will be completely filled
→ Kneading blocks work more intensively
→ Separation of two vacuum sections is possible

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Adjustment of residence time

Residence time

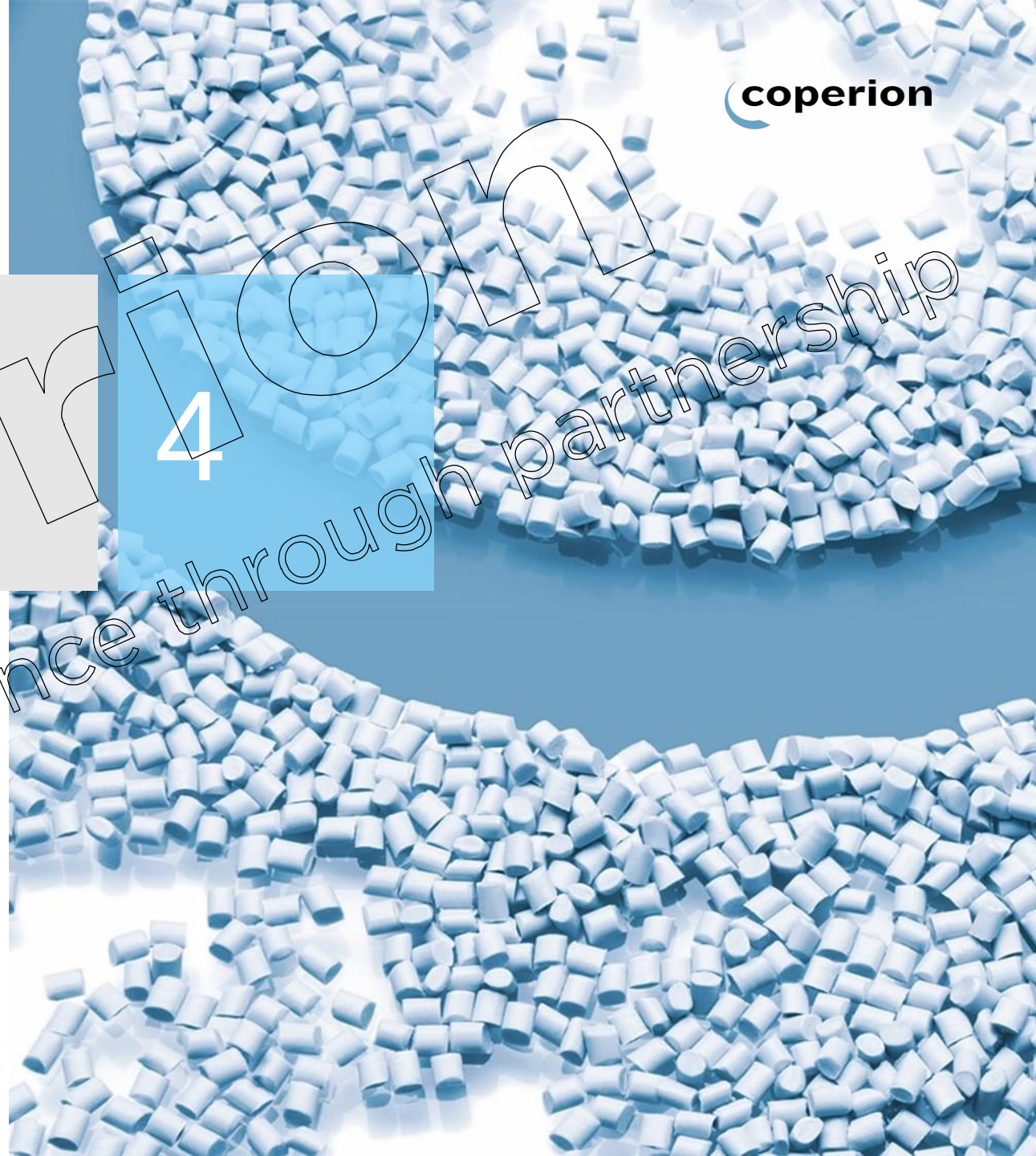




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Kneading blocks

4



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Kneading blocks

Mixing mechanisms in twin screw extruders

Dispersive Mixing
=
Break up of agglomerates and aggregates

Distributive Mixing
=
Distribution of primary particles

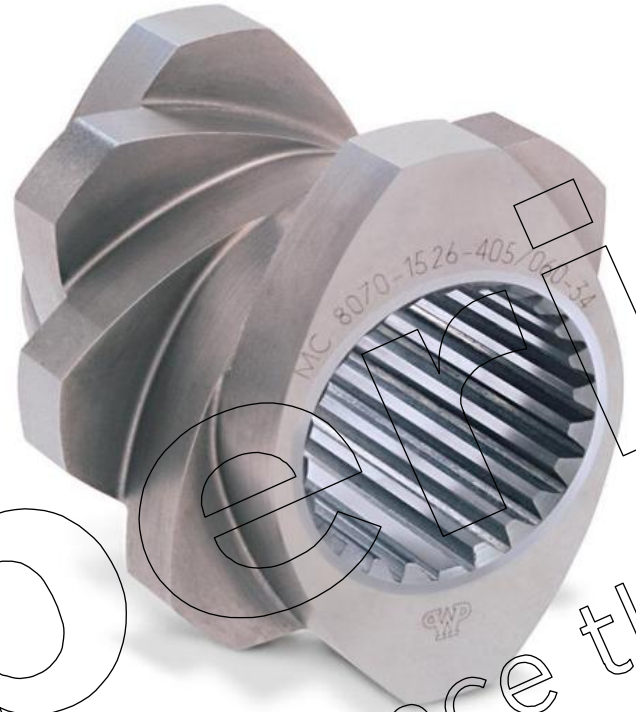


Shear stress
elongational stress

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Kneading blocks

Working principle



● ... Product

T ... Axial Transportation

M ... Distributive mixing

K ... Dispersive mixing/kneading

The impact of the staggering angle

< 45°	> 45°
• improved transportation • reduced mixing	• reduced transportation • improved mixing

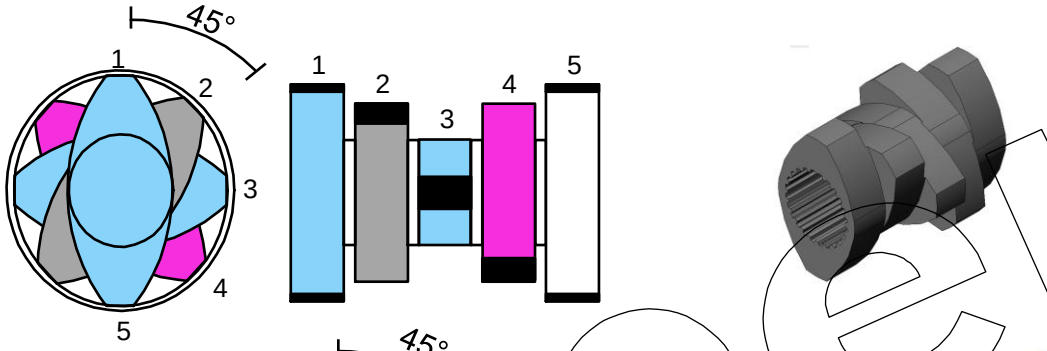
The impact of the width of the disk

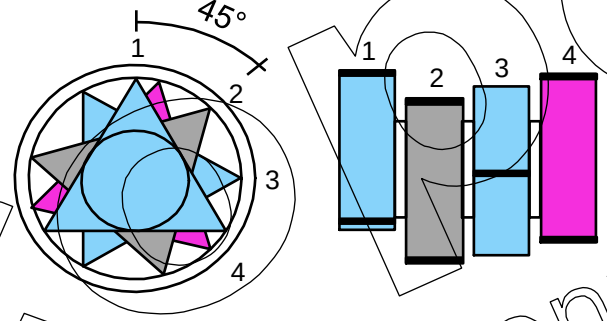
Small / narrow	Big / wide
• improved distributive mixing • reduced dispersive kneading	• reduced distributive mixing • intensive dispersive kneading

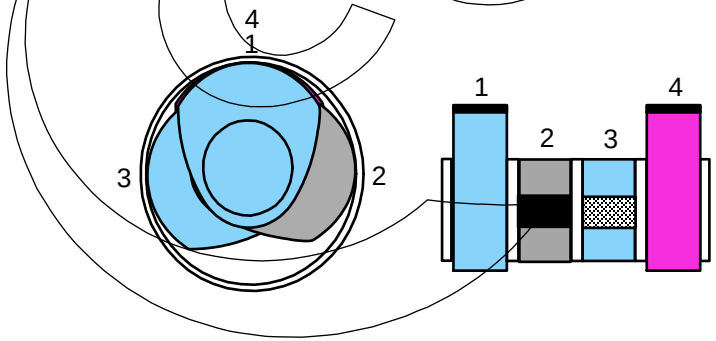
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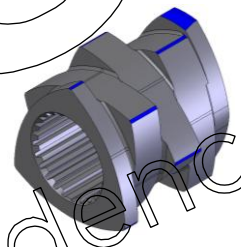
Kneading blocks

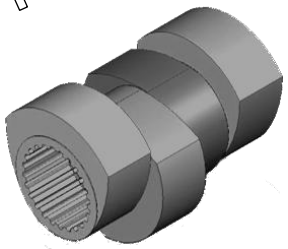
Comparison of 1-, 2- and 3-flighted kneading blocks

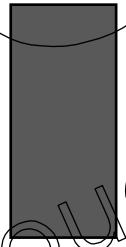
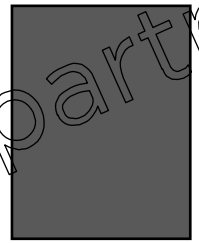
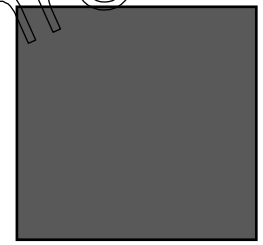
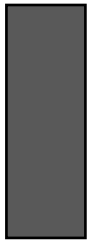








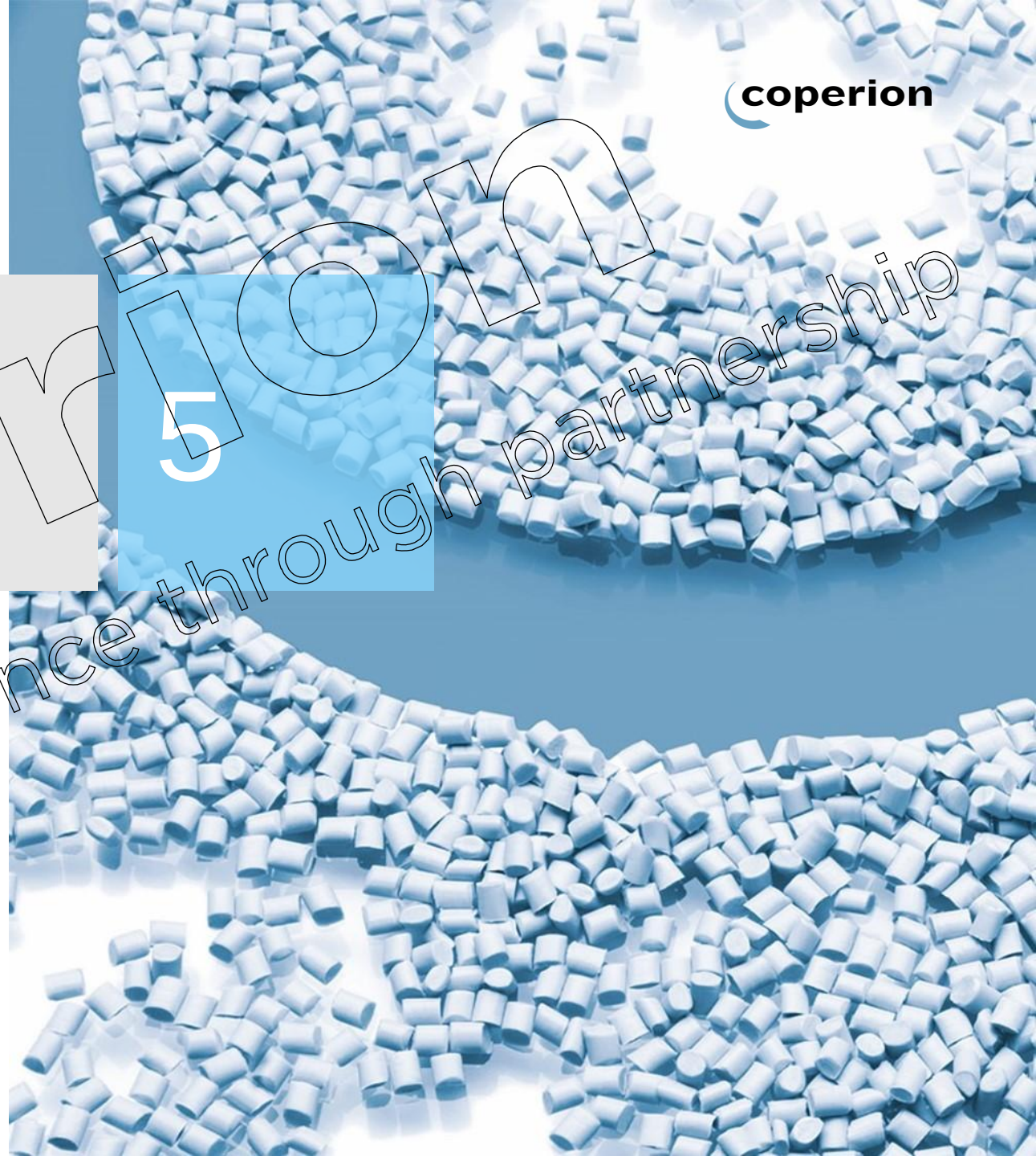


Mixing effect (distribution)	Shearing (dispersion)
	
	
	

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Mixing elements

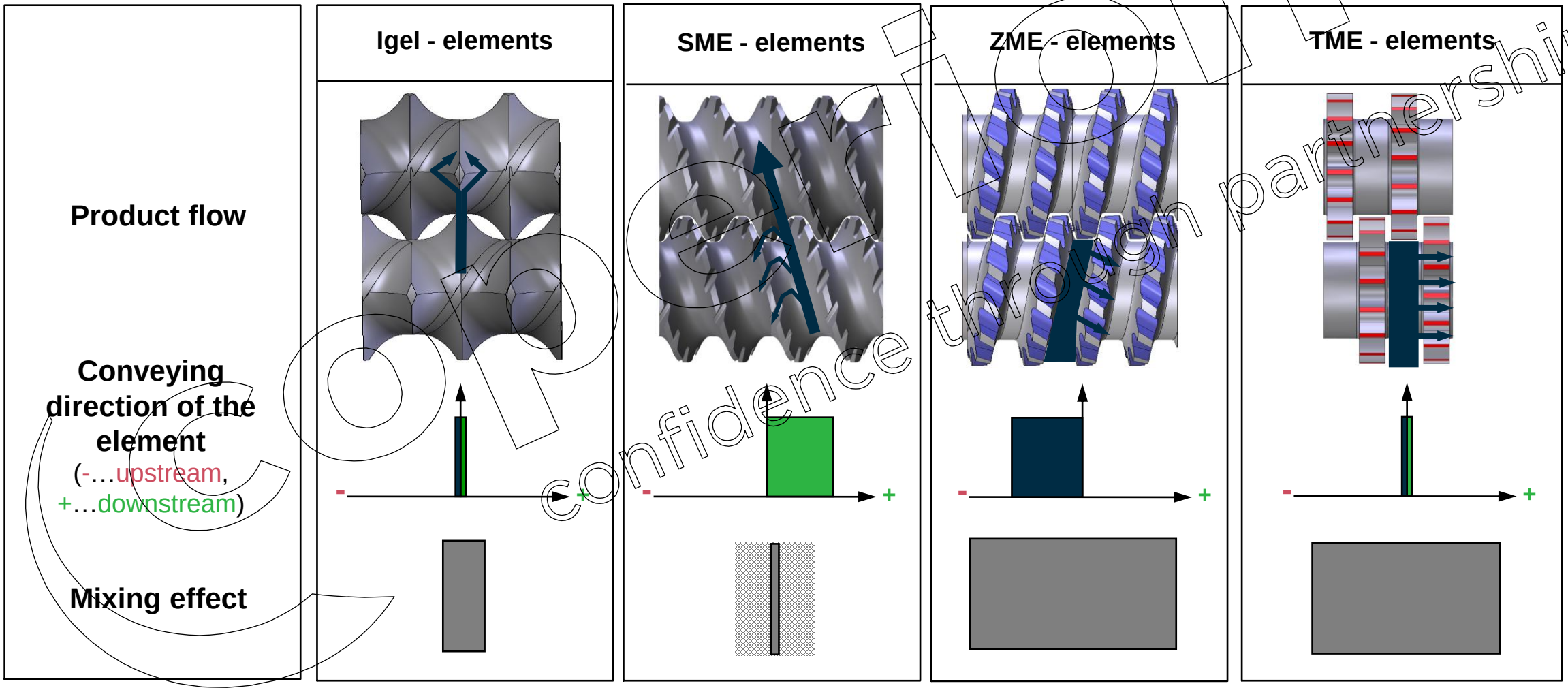
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Mixing elements

Product transport and distributive mixing



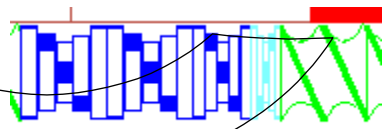
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Unit Operations: Processing Section

Example for improved dispersive and distributive mixing by using ZME

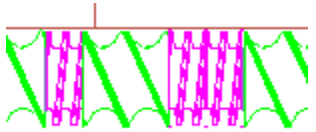


Pressed plate - screw (PA+GF)。





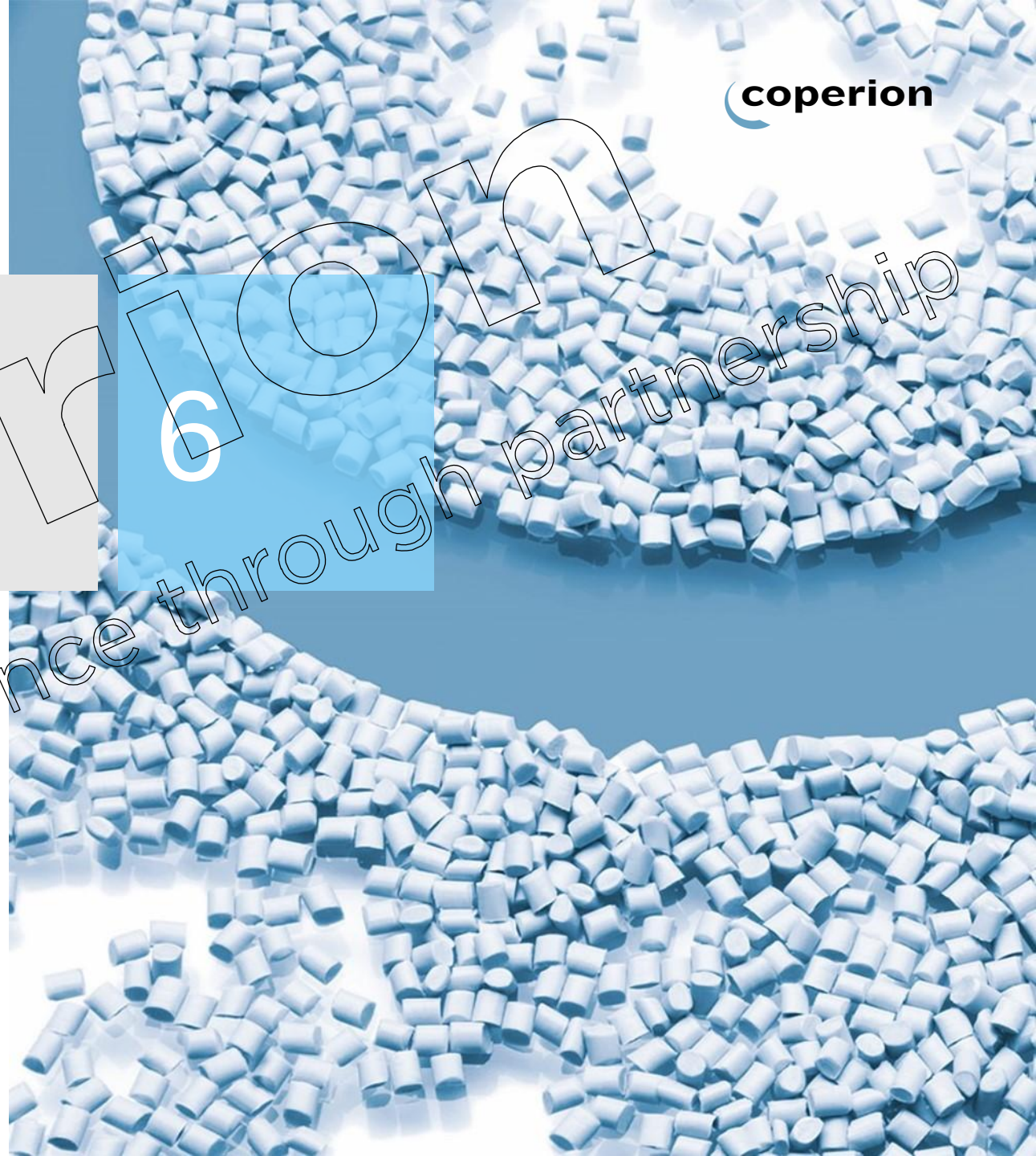
Pressed plate - optimized screw (PA+GF)。



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Particularities of assembly

6

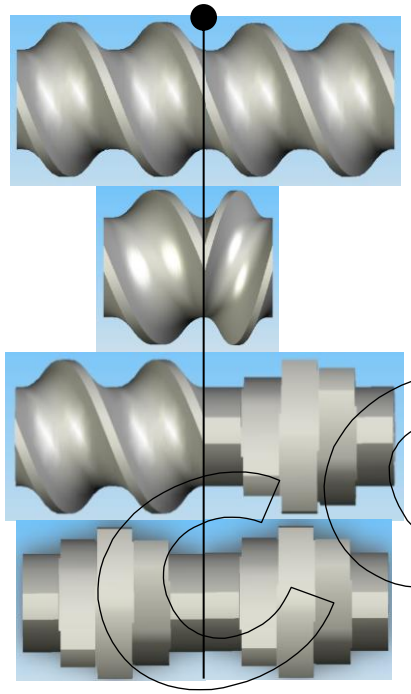


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Particularities of assembly

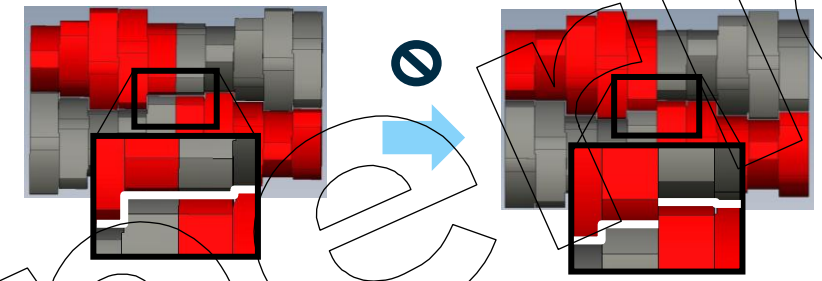
Element transition

Element transition with same profile

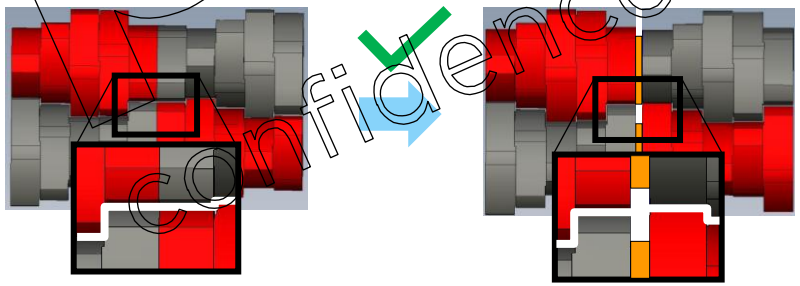


- Element transition is continously
- Enough axial clearance is ensured

Element transition with same profile but different staggering angle

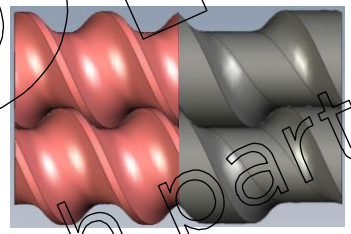


- Element transition is not continously
- Enough axial clearance is not ensured

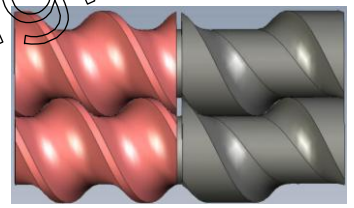


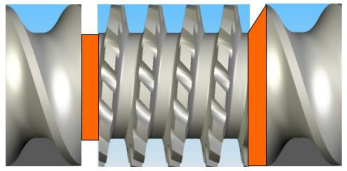
Spacer needs to be installed
➔ Enough axial clearance is ensured

Element transition with different profile e.g. 2F -> 1F

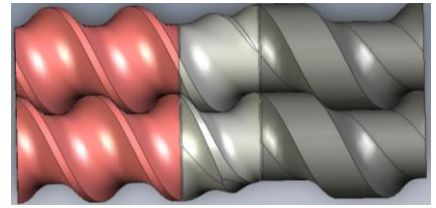


axial clearance is not ensured





Spacer needs to be installed
➔ Enough axial clearance is ensured

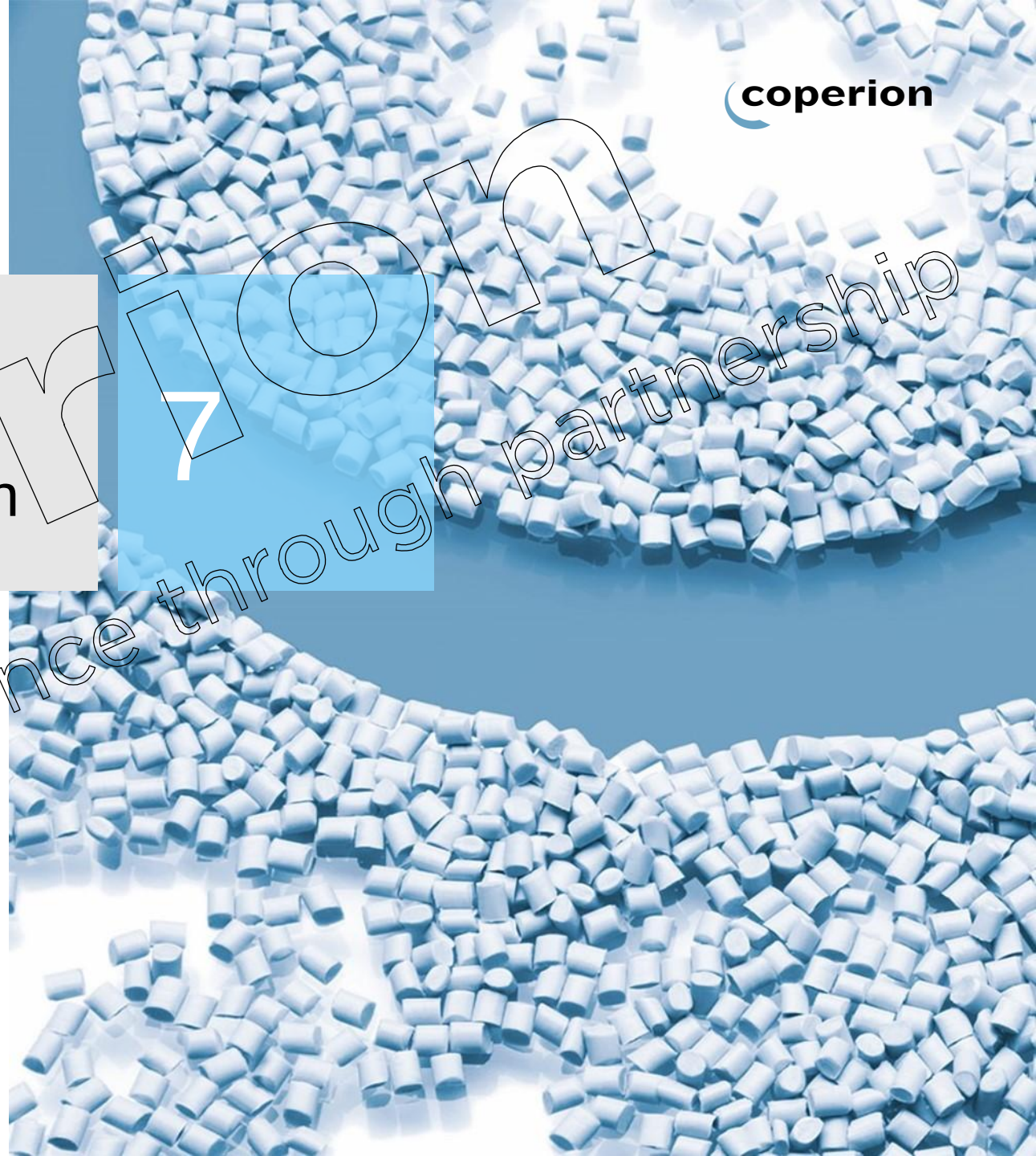


Installation of Transition Element to ensure axial clearance

Collection
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Material of construction / wear reduction

7



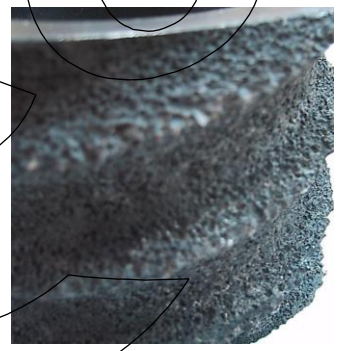
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Material of construction / wear reduction

Wear / MoC



Abrasive wear



Corrosion

Material code	Material	Design	Hardness max. (HRC)	Area of application** Wear	Corrosion
WP 00	Nitriding steel (standard), nitrided	Solid	> 700 HV	••	•
WP 40	Standard	Ni-based crest welding	45	•••	••
WP 05	Martensitic (Cr-Mo) stainless steel	Solid	50	••	•••
WP 15	Fe-based PM material	Composite material	65	••••	•
WP 25	Fe-Cr-based PM material	Composite material	60	•••	•••
WP 28	Cr-Ni stainless steel	Ni-based crest welding	45	•	••••
E 60	High speed tool steel PM material	Composite material	65	•••••	•
E 12	High speed tool steel PM material	Composite material with CVD coating	65	••••••	•
WP 16	Ni-based material	Ni-based crest welding	45	•	•••••

** • = Low, •••••• = High

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Thank you for your attention.

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For Food, Health and Nutrition

